The University of Chicago

TRANSFER OF RESPONSE IN HUMAN SUBJECTS

A PART OF A DISSERTATION SUBMITTED TO THE GRADUATE FACULTY IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

By
HAROLD GULLIKSEN

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TRANSFER OF RESPONSE IN HUMAN SUBJECTS [1]

BY HAROLD GULLIKSEN

From the Psychological Laboratory of the University of Chicago

A wide variety of investigations have appeared in the literature under the general head of transfer. They differ both in the factors varied experimentally, and in the criterion of transfer. As to the factors varied experimentally, sometimes the response has been kept constant, and the stimulus varied; sometimes the reverse has been done. Sometimes the stimulus and response have both been kept constant and the context altered. In some experiments both the stimulus and response have been altered, as has been the case in many of the experiments on transfer in education, and on transfer in maze learning. For instance, when a rat trained on one maze is tested on other mazes, the mazes (stimuli) are different, and the adjustments made (responses) are different in each case. This variation of several factors at once makes it difficult to analyze and interpret the data.

As to the criteria of transfer, two different ones have been used. One criterion is change in the subject's ability to learn new things. This is used for example in most of the animal experiments demonstrating transfer on the basis of relative rather than absolute factors in the stimulating situation. In most of these experiments punishment and reward are continued in the testing series just as they are in the training series, so that the animal is *learning* how to respond in the test series as well as in the training series. The other criterion is change in the subject's stimulus-response connections. This criterion is used for example in a few of the animal experiments on transfer. For example in the work of Klüver, of Lashley, and of Pavlov, the differential punishment and reward are not given during the test series, but only during

[1] This experiment was carried on under the direction of Dr. Harvey A. Carr and I wish to express my appreciation for his valuable criticism and advice.

the training series, so that during the test series the animal does not have the same opportunity to learn how to respond, that he has during the training series. With the first technique it is impossible to tell to what extent the results are due to increased rapidity of learning of new problems, and to what extent to an immediate transfer of a given response from the old stimulus to the new one. By using the second criterion, the factor of immediate transfer of a given response from the old stimulus to the new one, is isolated.

In this experiment we are dealing only with the type of condition in which the context and response are kept constant and the stimulus is altered; and the criterion of transfer is the change brought about in the functioning stimulus-response mechanisms in the organism. It has been shown that when an organism has been trained to give a certain response to one stimulus, it sometimes without further training gives the same response to certain other stimuli. For example Watson found that a child trained to show fear whenever a rat was presented, would, without any further training, show fear to a rabbit, a fur muff, a pigeon, and a Santa Claus mask. None of these objects had formerly called forth the fear response. Furthermore this transfer of response did not extend to *all* other stimuli. It was not given to the blocks the child played with, to the room, to the table, nor to the experimenter. We see here an illustration of the fact that when an organism has been trained to give a response to one stimulus it may without further training give the same response to certain other stimuli, but not to all other stimuli. Dr. Watson, however contented himself with simply stating the specific facts shown by his experiment without attempting to find the general *differentiating* principles involved. Furthermore he treats his data as if the test stimuli used fell into two distinct classes; 1. stimuli to which the response did transfer, and 2. stimuli to which the response did not transfer. Yum, on the other hand, working on 24 hour recall of paired associates, found evidence not for an all-or-none transfer, but a relationship between similarity of the test stimuli to the training stimuli, and the probability of recall. Klüver working with

monkeys, and Pavlov with dogs agree with Watson, in that they report their findings in terms of transfer, or no transfer, instead of in terms of the degree of transfer. Watson then reports transfer on an all-or-none basis for infants, and this agrees with the reports of Pavlov for dogs, and of Klüver for monkeys; while Yum working with adult human subjects reports that the degree of transfer depends on the degree of similarity and is not an all-or-none matter. It is important to know whether transfer is an all-or-none affair, or is exhibited in varying degrees. This is one of the problems that will be taken up in this paper.

The present investigation is an attempt to set up an experiment which will get at some of the differentiating principles in accordance with which the new stimuli will or will not call out the old response. A comparatively simple set-up was arranged for using adult human subjects under conditions more closely paralleling those generally used for animals. The subject was first trained to give two antagonistic responses, one to each of two classes of stimuli. Then with the context kept constant, other stimuli were presented which bore varying relations to the two stimuli of the training series. The subject was required to give either one of the two antagonistic responses to each of the new stimuli. The responses of the subject, and the relations between the training and test stimuli were then examined to determine what generalizations would enable one to predict which of the two antagonistic responses would be given to any test stimulus.

Training Procedure

The subjects were trained to react differentially to two different series of visual stimuli, namely two different types of geometrical angles. A representative sampling of the training stimuli used is shown in Plate I. There were two different series of stimuli used.

One group of subjects was trained, using series *X* (Plate I), to give one response to stimuli of type *x*1, and an antagonistic response to stimuli of type *x*2. There were 100 stimuli each of type *x*1, and *x*2. As can be seen from Plate I the different stimuli of series *X* are angles which vary in the length and thickness of the sides of the angle, but are all alike in that the point of each angle is directed toward the upper right hand corner. The difference between the members of type *x*1, and type *x*2 is that the stimuli of type *x*1 are all 100° angles, while the stimuli of type *x*2 are all 25° angles. So in series *X* the differential reaction of the subject is made on the basis of the *size* of the angle.

Another group of subjects was trained using series *Y* (Plate I), to give one response to stimuli of type *y*1, and an antagonistic response to stimuli of type *y*2. There were 100 stimuli each of type *y*1, and type *y*2. The members of series *Y* like those of series *X* are angles which vary in the length and thickness of the sides of the angle. The stimuli of series *Y* are all alike in that they are all 45° angles. The difference between members of type *y*1 and type *y*2 is that stimuli of type *y*1 are angles with the vertex directed toward the left, while type *y*2 is composed of angles with the vertex directed downward, so that in series *Y* the subject's differential reaction is made on the basis of the *direction* of the angle.

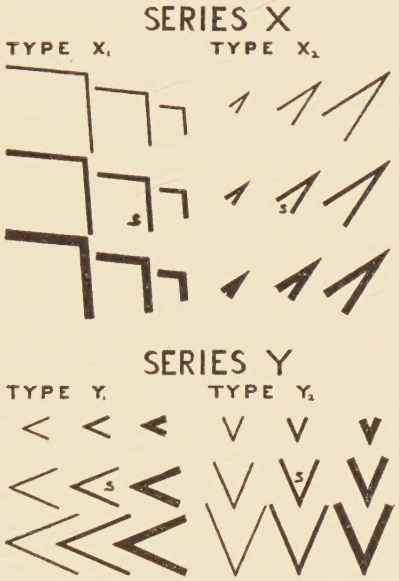


PLATE I

Each stimulus figure was drawn in india ink on a 5 x 6 inch card, $\frac{1}{16}$ inch thick, made of a special fiber board that is very tough and yet takes drawing or printing very legibly. These cards were then presented to the subject one at a time. The exposure period was about $1\frac{1}{2}$ seconds, and the interval between exposures was about $1\frac{1}{2}$ seconds. The cards were presented by a special type of tachistoscope designed to present long series of visual stimuli at any desired constant rate. This apparatus has been described in an apparatus note appearing in the *Journal of General Psychology*.

At each sitting which lasted about 15 minutes the subject was presented with and reacted to 200 of the training stimuli. Each subject was given four sittings, one a day at the same time on each of four successive days. The same group of 200 stimuli was presented to the subject at each sitting.

The differential response required of the subject was the movement of a small lever to the right for one type of stimulus, and to the left for the other type of stimulus.

The method of training is best explained by first giving the instructions that were presented to the subject.

This buzzer (indicating a buzzer hung just above the reaction lever) will sound at times during the experiment. You are to react to the stimuli appearing and dis-

appearing here (indicating the opening in which the cards were to be exposed to the subject) by moving this lever to one side or to the other, or by leaving it in the middle (illustrating by moving the lever). By reacting properly you can keep the buzzer completely silent. The buzzer should be silent both during the presentation of stimuli and between presentations of stimuli. Please do not talk about this experiment with anyone.

The apparatus was then set so that the buzzer would ring under the following conditions:

1. If the lever were moved to the right or to the left during the 1½ second interval between presentation of cards.

2. If the lever were left in the neutral position for over ¼ second after the presentation of any card.

3. If the lever were moved in the "wrong" direction (specified in more detail below) when a card was presented.

4. If the lever were held to the right or to the left for over ¼ second after the disappearance of any card.

This meant that in order to keep the buzzer silent, *i.e.* to react correctly, the subject had to learn to react in the following manner:

1. To keep the lever in the neutral position between presentations of cards.

2. To move the lever in the 'correct' direction within ¼ second after the presentation of each card.

3. To allow the lever to return to neutral within ¼ second after the disappearance of any card, and leave it there until the next card appeared. During the ¼ second allowed for reaction time, the buzzer would remain silent no matter whether the reaction lever were left in the middle, or pushed to the right or to the left.

It was possible that a constant error might be introduced into the results due to the fact that a movement to the right was easier for the subjects to make than a movement to the left, or vice versa. To control for this factor the following method was used. With some subjects the right side was 'correct' for stimuli of type *x*1, and the left side was 'correct' for stimuli of type *x*2; while for other subjects the right side was 'correct' for stimuli of type *x*2, and the left side was 'correct' for stimuli of type *x*1. The same reversal of direction of movement for two different groups of subjects was used as a control for those trained to discriminate stimuli of type *y*1 from stimuli of type *y*2.

This particular method of training was adopted because it could, with slight changes, be used on young children or on animals. The verbal instructions used could be eliminated by the substitution of punishment of some sort for the warning signal of the buzzer; the response was a manual one instead of a verbal one; a choice reaction was required; and the learning was simply through the trial and error method. All of these features though somewhat unusual[2] in the human work on Transfer, were adopted in this experiment because the method could then be used on young children or animals with only minor changes, and so genetic and comparative investigations could be made in a more direct manner than otherwise.

Test Procedure

The test stimuli used were also geometrical angles. They are all shown in Plate II, series A, and series B. These test stimuli always bore one of three possible general relationships to one or the other of the two types of stimuli used in each training series.

[2] Ruediger, Thorndike, Volkmann, Woodrow, Yum.

(1) Some were like one or the other of the two types of training stimuli in *size*; but exhibited different degrees of variation in *direction*. (2) Some were like one or the other of the two types of training stimuli in *direction*; but exhibited different degrees of variation in *size*. (3) Other test stimuli differed from the two types of training stimuli in both *size and direction*. The exact number and kind of variations used can be seen by an inspection of Plate II, and will be described in greater detail below, when results are given.

Method of presenting the test stimuli: In the usual work with human subjects the procedure has been to present the subjects with the training series until they have reached a certain criterion of learning and then inform them that they are now to be presented with a test series in which they will not be told whether they are right or wrong. Sometimes the instructions have included the information that some of the

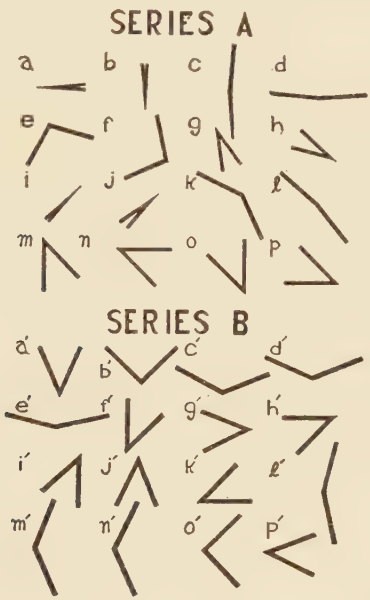


PLATE II

stimuli presented might not have been presented in the training series, but the subject is to react as seems best to him. Then the subject has been presented with the test series and his reactions recorded. With animals the same general procedure has usually been followed. The animal has been trained with punishment until it reached a certain criterion of learning and then has been presented with a long series of test stimuli without punishment.[3] In many of the experiments on animals punishment has been used in the test series.[4] In some work on transfer in rats I have found that during a test series of 30 successive trials the later reactions of the animal were frequently radically different from the first. In some cases it was noticed that even the

[3] Gayton, Pavlov, Washburn.

[4] Helson, Perkins, Wylie.

first one or two test trials consistently gave results different from those of the next eight test trials. This suggested the possibility that even though the animals had no instruction to the effect that they were being given a test series which differed from the training series in that punishment had been removed, nevertheless the difference between the training and test series was "noticed" sufficiently to cause the animals' reactions during the latter part of the test series to be different from their reactions during the earlier part. It seems that the first test trial made when the subject is all set to react to one of the regular training series is more indicative of the real transfer effect of that training series than the later test trials where one has not only the influence of the training series but also the influence of the preceding part of the test series. Therefore the customary method of presenting the test stimuli in a group after a certain criterion of learning had been reached was abandoned and the following procedure adopted.

The items of the test series were interspersed among the items of the training series at certain determined points, so that as far as the subject was concerned there was no difference between the stimuli of the test series and the stimuli of the training series. After a little preliminary experimentation it was found that most of the subjects had the training problem fairly well mastered after the presentation of about 40 of the training stimuli, so the test and training stimuli were arbitrarily arranged in the following order. Forty cards of the training series were presented, then one card of the test series, then 10 cards of the training series, then one card of the test series, then 10 more of the training series, and one of the test series, and so on, the series finally ending with the presentation of 10 cards of the training series. Two hundred training stimuli and 16 test stimuli were presented to the subject in this manner at a single sitting. With this method any two test stimuli were separated by 10 presentations of the regular training stimuli.

While this method has the disadvantage of introducing the various test stimuli at different stages of the learning process, it was thought worth trying because it minimizes the possibility of the results being altered by the discovery of the difference between the training and test series.

When the test stimuli were presented the cards themselves automatically adjusted the apparatus so that the buzzer would sound (¼ second after the presentation of the card) only if the reaction lever were left in the neutral position. Movement of the lever either to the right or to the left would keep the buzzer silent. The object was to see what response the subject would give to the test stimuli, and to discover how that response would be influenced by the type of training given.

In order to discover the difference between the test and training series when this procedure was used the subjects would have to notice that about every 10th card was different from the rest and that for those cards it did not matter in which direction the lever was moved. Furthermore they had only 1½ seconds to discover that the lever could be moved in either direction without the buzzer sounding. At the close of the experiment the subjects were asked to describe their solution of the problem. The question was framed as follows: "If you were instructing some one else how to react to this situation so that he would not have to go through the same trial and error process you did, what would you tell him?" Whenever a subject showed in his reports that he had discovered that the direction of movement was indifferent for some of the stimuli, his results were discarded. The results of nine subjects were discarded on this basis.

The subjects used were 72 students of elementary and advanced psychology in the University of Chicago. Three experiments were made, each with 24 subjects.

In the first experiment the subjects were trained on series *X* (Plate I) and tested with series *A* (Plate II). The 24 subjects used in this group were divided into two groups of 12 each, one group being trained to move the lever to the right for stimuli of type *x*1 and to the left for stimuli of type *x*2; the other group being given just the opposite training.

In the second experiment the subjects were trained on series *Y* (Plate I), and tested in the manner described with series *A* (Plate II). The 24 subjects used in this group were divided into two groups of 12 each. One group was trained to move the lever to the right for stimuli of type *y*1, and to the left for stimuli of type *y*2. The other group was given just the opposite training.

In the third experiment the subjects were trained on series *Y* (Plate I), and tested with series *B* (Plate II). The 24 subjects used in this group were divided into two groups of 12 each and each group given the type of training opposite to that of the other group (as described above), to control for the effect of direction of movement.

Results

About ten percent of the subjects discovered that, for some of the test stimuli used, the direction of movement was indifferent, and their results were discarded. This left 12 subjects in each group as explained above, and as each subject had four sittings he reacted to each of the test stimuli four times. Pooling the results for the 12 subjects in a single group we have 48 responses in each group to each test stimulus. Although the subject usually reacted by moving the lever to the right or to the left, sometimes the subject failed to respond when the test card was presented, and sometimes the response consisted in moving the lever quickly back and forth from right to left. Only movements definitely to the left, or definitely to the right were considered in tabulating the results. The various ambiguous movements or failures to move were omitted. This means that the percentages calculated below are each based on from 40 to 48 responses.

The number of movements definitely to the left was added to the number of movements definitely to the right, and this sum was divided into the number of movements to the right, or into the number of movements to the left, thus giving the percentage of movements to the right, or the percentage of movements to the left. These data are given in the following tables. In most cases the percentage of movements to the right was calculated if a movement of the lever to the right had been required in response to stimuli of type *x*1, or type *y*1;

while the percentage of movements to the left was calculated if a movement of the lever to the left had been required in response to stimuli of type $x1$, or type $y1$. This may be termed the percentage of responses the subject made 'as if' he had been responding to stimuli of type $x1$ (in experiment 1), or to stimuli of type $y1$ (in experiment 2 or 3). With this method of tabulating results a 100 percent record in experiment 1 for any test stimulus will indicate that in all tests, and by all subjects that particular test stimulus was reacted to just as if it had belonged to stimuli of type $x1$. In experiments 2 and 3, 100 percent recorded for any test stimulus will indicate that in all tests and by all subjects that particular test stimulus was reacted to just as if it had belonged to stimuli of type $y1$. On the other hand 0 percent will indicate (in experiment 1) that in all tests and for all subjects that particular test stimulus was reacted to just as if it had belonged to stimuli of type $x2$. In experiments 2 and 3, 0 percent recorded for any test stimulus indicates that it was always reacted to just as if it belonged to stimuli of type $y2$.

Table I gives the data for the subjects trained to dis-

TABLE I

Training Stimuli: The two types were the same in direction (pointing towards the upper right hand corner) but different in size, a 100° and a 25° angle being used.

Test Stimuli: The direction was the same as that of the training stimuli, but the size was different. The sizes used were 5°, 12°, 140°, and 175°.

Tabular data give the percentages of cases in which each of the test stimuli elicited the response which was given to the 100° training stimulus.

Size of Angle in Degrees	5°	12°	140°	175°
% responses right for subjects trained to move lever right for stimuli of 100°	20	16	71	55
% responses left for subjects trained to move lever left for stimuli of 100°	2	9	77	74
Results for all subjects used in experiment 1	11	12	74	64

criminate a 100° from a 25° angle, direction being the same (series X), and tested on angles which differed from both of the training stimuli only in size.

In the majority of cases each test stimulus elicited the response which had been given to that training stimulus which most resembled it in size. For example, in 74 percent of the

cases the 140° test stimulus elicited the response which had been given to the 100° training stimulus. In 12 percent of the cases the 12° test stimulus elicited the response which had been given to the 100° training stimulus. This means that in 88 percent of the cases the 12° test stimulus elicited the response which had been given to the 25° training stimulus.

The frequency with which a test stimulus elicited the response which had been given to the training stimulus most like it in size, decreased slightly with the increase of the size difference. For example, the 175° test stimulus elicited the response which had been given to the 100° training stimulus less frequently than did the 140° test stimulus.

In this experiment none of the test stimuli were identical with either of the training stimuli; and we have no data as to the strength of the habit developed in the training series as a norm of comparison.

Table II gives the data for the subjects trained to discriminate direction of angle, size being the same (series *Y*), and tested on angles which were like one or the other of the training stimuli in direction, but which exhibited varying degrees of difference in size.

In the majority of cases the angles pointing down in the test series elicited the response which had been given to the angles of the training series which pointed down; likewise in a majority of the cases the angles pointing left in the test series elicited the response which had been given to the angles of the training series which pointed left. These statements are based on the fact that most of the percentage records given exceed fifty.

The frequency with which a test stimulus pointing in a given direction elicited the response which had been given to the stimulus of the training series pointing in the same direction, decreased as the size difference increased.

With the larger differences in size, the percentages approximated fifty, as in the case of the 135° angle with vertex down, or the 175° angle with vertex left. In these cases the subjects apparently reacted on the basis of chance.

There were two rather marked exceptions to the rule of

TABLE II

Training Stimuli: The two types were the same in size (45°) but different in direction of angle—pointing down versus pointing left.

Test Stimuli: The direction was the same as that of one or the other of the two types of training stimuli, but the size was different. The sizes used were 5°, 45°, 90°, 115°, 135°, 155°, and 175° for each of the two directions. Results for the two directions are tabulated separately, as follows:

Test Stimuli with Vertex Down

Tabular data give the percentages of cases in which each of the test stimuli elicited the response which was given to the training stimuli with vertex down.

Size of Angle in Degrees	5°	45°	90°	115°	135°	155°	175°
% responses left for subjects trained to move lever left for stimuli with vertex down	79	100	78	61	57	*30*	*40*
% responses right for subjects trained to move lever right for stimuli with vertex down	76	100	64	64	37	*24*	*43*
Results for all subjects used in experiments 2 and 3	78	100	71	62	47	*27*	*42*

Test Stimuli with Vertex Left

Tabular data give the percentages of cases in which each of the test stimuli elicited the response which was given to the training stimuli with vertex left.

Size of Angle in Degrees	5°	45°	90°	115°	135°	155°	175°
% responses right for subjects trained to move lever right for stimuli with vertex left	87	96	90	93	89	72	37
% responses left for subjects trained to move lever left for stimuli with vertex left	87	98	91	91	81	59	58
Results for all subjects used in experiments 2 and 3	87	97	91	92	85	66	47

reaction to the test stimuli on the basis of their directional similarity to one or the other of the two types of training stimuli. In the majority of the cases the 155° and 175° angles with vertex down elicited the response which had been given to the training stimulus with vertex left (see figures underlined in Table II). This phenomenon will be discussed more in detail later.

Table III gives the data for the subjects trained to discriminate a 100° from a 25° angle, direction of angle being the same (series *X*), and tested on 100° or 25° angles which differed from the angles of the training series in direction.

In the majority of cases each test stimulus elicited the response which had been given to the training stimulus of

TABLE III

Training Stimuli: The two types were the same in direction (towards the upper right hand corner), but different in size, a 100° and a 25° angle being used.

Test Stimuli: The size was the same as that of one or the other of the two types of training stimuli used, but the direction was different. In one case the stimuli pointed up and slightly to the left; in the other, to the right and slightly down.

Tabular data give the percentages of cases in which each of the test stimuli elicited the response which was given to the stimuli of the same size in the training series.

TEST STIMULI OF 25°

Direction of Vertex of Angle	Up and Slightly Left	Right and Slightly Down
% responses left for subjects trained to move lever left for stimuli of 25°	100	79
% responses right for subjects trained to move lever right for stimuli of 25°	76	81
Results for all subjects used in experiment 1	88	80

TEST STIMULI OF 100°

Direction of Vertex of Angle	Up and Slightly Left	Right and Slightly Down
% responses right for subjects trained to move lever right for stimuli of 100°	87	81
% responses left for subjects trained to move lever left for stimuli of 100°	93	78
Results for all subjects used in experiment 1	90	80

the same size. That is, the response given to the 100° angles was, in the majority of cases, like the response given to the 100° angles in the training series; and the response given to the 25° angles was in the majority of cases like the response given to the 25° angles in the training series.

In each case the variation in direction was $67\frac{1}{2}$ degrees from the direction of the training series, but there is no clear indication that this same variation in direction produced the same disturbance of the response in each case.

Table IV gives the data for the subjects trained to discriminate direction of angle, size being the same (series *Y*), and tested on angles of the same size (45°), but varied as to direction.

In the table the general direction of a line of figures from the center indicates the direction of the vertex of the angle for which those figures indicate the percentage of responses.

For example, the line reading 97, 98, 96, points to the left, and indicates the results for a test stimulus of 45° pointing left, *i.e.* a test stimulus identical with the training stimulus,

TABLE IV

Training Stimuli: The two types were the same in size (45°) but different in direction of angle—pointing down versus pointing left.

Test Stimuli: The size was the same as that of the training stimuli, but the direction was different. The directions used were straight up, straight down, straight right, and straight left, with two directions between adjacent ones of these, as shown in the table.

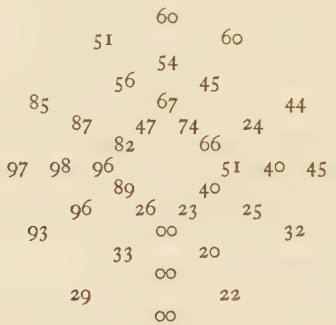
Tabular data give the percentages of cases in which each of the test stimuli elicited the response which was given to the training stimuli with vertex left.

(The general direction of the line from the center indicates the direction of the point of the angle.)

The inner circle shows the percent responses right for subjects trained to move the lever right for stimuli pointing left.

The next circle of figures shows the percent responses left for subjects trained to move lever left for stimuli pointing left.

The outer circle of figures shows the results for all subjects used in experiments 2 and 3.



and used as a norm to measure the accuracy of the habit established. The results show that in 97 percent of the cases the 45° angle pointing left elicited the response which had been given to the 45° angles pointing left in the training series. This means that in 3 percent of the cases this same test stimulus elicited the response which the subjects had been trained to give to the 45° angle pointing down. The other stimulus of the test series used as a norm is indicated in the line reading 00, 00, 00. This line points down from the center, and so indicates the results for the test stimulus with vertex down. In this case, 0 percent responses means that this stimulus was always reacted to the same as a 45° angle with vertex down in the training series.

Variations of $22\frac{1}{2}$ degrees from the stimulus pointing left are indicated by the two lines reading 85, 87, 82; and 93,

96, 89. As can be seen, test stimuli showing variations in direction of $22\frac{1}{2}$ degrees still in a majority of cases brought the response which had been given to the 45° angles pointing left. Likewise the two test stimuli varying $22\frac{1}{2}$ degrees in direction from the training stimulus pointing directly down are indicated in the lines reading 29, 33, 26; and 22, 20, 23. That is, the two test stimuli which differed $22\frac{1}{2}$ degrees in direction from the training stimulus pointing down elicited, in 22 percent and 29 percent of the cases, the response which had been given to the training stimulus with vertex left, or, in other words, in 78 percent and 71 percent of the cases these test stimuli elicited the response which had been given to the training stimuli with vertex down.

The values for variations of $67\frac{1}{2}$ degrees or more in direction are ambiguous in import. Possibly the subjects were reacting by chance.

In summarizing the preceding four tables we may designate transfer as 'unambiguous' when the percentage of responses tabulated was either 0 percent or 100 percent. Varying degrees of ambiguity of transfer would then be indicated by percentages varying from 100 percent on the one hand and from 0 percent on the other, toward 50 percent which may be termed 'complete ambiguity' of transfer, *i.e.* half the responses are in one direction, and half in the other.

When the subject has been trained to discriminate angles of two different sizes with direction of angles the same, there is transfer to novel stimuli on the basis of correspondence of size of angle. The degree of ambiguity of the transfer increases with increasing differences between the size of angle of the training and test stimuli. From the data of this experiment no confident statements can be made regarding the relationship between the degree of ambiguity of transfer, and degree of variation in direction.

When the subject has been trained to discriminate angles of two different directions with size the same, there is transfer to novel stimuli on the basis of correspondence of direction of angle. The degree of ambiguity of the transfer increases with increasing differences between the training and test stimuli in either size or direction.

The verbal reports of the subjects as to the characteristic which determined their reaction showed that one could not decide on a-priori grounds how the subject would verbalize his discrimination. In experiment 1, where the subjects were theoretically discriminating on the basis of the size of the angle, some of the subjects gave vague explanations in terms of the direction in which the arm of the angle pointed, as contrasted with the direction in which the apex of the angle pointed. In experiments 2 and 3, where the subjects were theoretically discriminating on the basis of the direction of the angle we again get a wide variety of reports, some reporting that they were reacting to the direction of the point of the angle, some to the direction of the opening. One subject distinguished between 'V's' and 'Arrows' and one between 'horizontal' and 'vertical.'

An attempt was next made to see how the subjective "similarity" of the test stimuli to the training stimuli would correlate with the percentage of responses. This method had the advantage of greater generality than the method of measuring some objective factor such as size or direction of angle, for stimuli which varied in size, or in direction, or in both could all be grouped together, and dealt with at once instead of being treated separately as in the preceding tables. So a separate experiment was conducted in which the subjects were given two sample cards of the training series, and the stack of 16 cards of the test series, with the following instructions:

> Here is a group of cards. You are to sort them with respect to their apparent similarity, as to the general appearance of the figure on the cards, to these two cards (indicating the two representative cards of the training series, which were placed at opposite corners of the table), so that finally they will be arranged in order of their similarity and dissimilarity to the two end cards. That is, as you go in this direction (indicating from left to right) the cards will become more like this card (indicating the card of the training series at the right) and less like that card; (indicating the card of the training series at the left), and conversely, as you move in the other direction the cards will become more and more like that card, and less and less like this card.

If the subjects asked just what was meant by 'similarity' they were told to interpret the word as they wished.

The subject then sorted the cards and afterwards was

asked to indicate a point which he thought was the neutral point where the cards were no more like one extreme than like the other extreme. His judgments were then recorded.

The above procedure was repeated with 48 subjects, 24 of whom had already served in the earlier part of the experiment, and 24 of whom were new subjects. Each subject was given three sorting tasks.

1. To sort the cards of test series *A*, the sample extremes being 's' of type $x1$, and 's' of type $x2$ of series *X*, (see Plate I).

2. To sort the cards of test series *A*, the sample extremes being "*s*" of $y1$, and "*s*" of $y2$, of series *Y* (see Plate I).

3. To sort the cards of test series B, the sample extremes being '*s*' of $y1$, and '*s*' of $y2$, of training series *Y* (see Plate I).

This gave three series of judgments of similarity made by 48 judges, which may be compared with the responses which were obtained in the earlier experiments, to see what relation there is between subjective judgments of similarity and the subject's reactions under the conditions of this experiment.

Although the subjects complained that they did not know what to do with such a collection of stimuli, and although the results for the different subjects gave a very wide scatter, yet it was found that when these results were pooled, the rank order of judged similarity and the rank order as to percentages of responses gave a correlation of .89 in experiment 1, .83 in experiment 2, and .93 in experiment 3. This certainly indicates a positive relationship between order of judged similarity and percentages of responses, although the correlation is probably spuriously high, since the probable error of a correlation determined from 16 cases is large, and the figures used as stimuli were selected because they showed marked differences, which would make the observed correlation still higher. The correlation can be interpreted as indicating that with the present set-up, some of the factors which affect the sorting of the cards with respect to similarity also affect the ambiguity of transfer.

The definite inverse relationship between ambiguity of transfer and similarity of test stimulus to the corresponding training stimulus make it rather certain that the similarity

of the test figure to the corresponding training figure is the principle factor influencing the subject's response to the test stimuli. However, it is well to investigate several other possible factors to be certain that this apparent influence of similarity is not in reality due to some extraneous uncontrolled factors in the experiment.

a. Chance Variation.—In experiments on animals where the same sort of imperfection in transfer has been shown it has usually been ignored or else dismissed with the statement that probably it represents some accidental variation in performance.[5] This hypothesis will not apply here. The correations of .83 to .93 between order of percentages of responses, and order of judged similarity cannot be explained as due to any chance influence.

b. Direction of Movement.—This source of error was controlled (as explained above) by giving one half of the subjects a training just opposite to that of the other half. An inspection of the tables shows that in general when the training was reversed, the response of the subject was also reversed.

c. Type of Discrimination.—It is possible that the particular type of discrimination used is responsible for the results obtained. This factor was somewhat ruled out by having two different sorts of discrimination made; one on the basis of size of angle, and the other on the basis of direction of angle. The same results were obtained with each type of discrimination. Other work shows that the same sort of result holds for nonsense syllables, meaningful words, and complex figures.[6] It would be desirable to test still other types of discrimination. I have evidence from work done on rats with size discrimination, that the same sort of result is obtained there also. It seems safe to conclude that the particular type of discrimination made is not a dominant factor.

d. Order in Which Test Stimuli Were Presented.—The sixteen test stimuli used in any one experiment were presented to each subject in the same order at each sitting. It may be

[5] Helson, Perkins, Washburn.

[6] Yum.

that this order influenced the percentage of times the subject would respond to a given test stimulus by a movement to the right or to the left. To determine the extent of the influence of this factor the correlation between order of the test stimuli with respect to percentages of responses, and order of presentation was computed, and found to be .007 for experiment 1; — .13 for experiment 2; and — .26 for experiment 3. This shows that the order of the test stimuli relative to each other was not a dominant factor in the determination of the subject's response, although it was probably a slight factor in some cases.

e. Preceding Movements.—It may be that the series of movements made in response to the ten members of the training series which preceded any test stimulus predisposed the subject to make the next movement in a particular direction regardless of what figure was presented. No special control was run for this factor alone, but we may pool the results from the three series of tests, and compare the percentages of responses in each of the cases where the preceding series of ten movements had been identical. The average percentage of responses following any particular arrangement of stimuli may be taken as the best guess as to the effect of that order of movement. Then this average may be correlated with each of the individual members that go to make up that average, to give a rough measure of how much scatter there is about the central tendency. This correlation was found to be .53. This shows that the direction of the preceding ten movements was a slight factor, but certainly was not dominant over the actual character of the figure shown.

The evidence then shows that these five factors just considered probably had a slight influence on the response in some cases; but the primary factor was the similarity of the test to the training figures.

Discussion

The test stimuli used in the present experiment cannot be satisfactorily divided into two classes; those which are 'equivalent' to the stimuli of the training series (as shown by

the fact that the response to them was very similar to that given to the corresponding training stimulus), and those which are 'non-equivalent' to the stimuli of the training series (as shown by the fact that the response to them is a chance response). Rather the stimuli used fall into a series showing all degrees of change in percentages of responses from almost 100 percent like the response given to one or the other type of training stimulus to a practically chance or 50 percent response. This fact has been demonstrated now by at least three experiments, the present one, Yum's,[7] and an experiment on animals (now in press in the *Journal of Genetic Psychology*) by the present author. In spite of marked differences in the experimental technique of these three experiments the fundamental conclusions are the same. This would seem to indicate that this relationship between similarity of test to training stimuli, and degree of ambiguity of transfer is a fundamental fact of learning, and not just a result which is due to the peculiarities of one experimental set-up.

This fact is of interest in connection with theories of learning. Dr. Lashley has reviewed the evidence showing that an adequate theory of learning must explain not only the formation of the specific $S \rightarrow R$ connection involved in learning, but also the fact that the formation of one $S \rightarrow R$ connection establishes not only that connection, but also

[7] It might be well to present here a brief summary of the principal ways in which the set-up of the present experiment differs from that of Yum's which is the only other work known to the present writer on direct transfer of the response to a new stimulus (as distinguished from ability to learn), in adult human subjects.

1. Yum's work was done with a paired associates technique using verbal responses; in this experiment a trial and error training technique was adopted using a manual response.

2. In his work the subjects knew when they were being trained, and when they were being tested; in this experiment the subjects were ignorant of this change from the training to the test situation.

3. In his work transfer was tested 24 hours after learning, in this experiment transfer was tested right in the learning situation.

4. In his work similarity was measured either by the identity of certain spatially separable elements (as the number of identical letters in two words) or by the pooled opinions of judges; in this experiment similarity was measured by certain objectively definable relationships (such as the size or the direction of the angle), which involved no identity of certain spatially separable parts of the stimuli and also by the pooled estimates of judges.

many others. It now seems clear that this problem cannot be taken care of in terms of simple 'equivalence' of some stimuli to those of the training series, and 'non-equivalence' of other stimuli to those of the training series. The problem is much more complex than this. Any theory of learning to be adequate must explain the fact that there are varying degrees of probability that the old response will be elicited by the new stimuli, and these probabilities may be any value between 0 percent and 100 percent.

Summary

1. There is transfer on the basis of size of the angle when the subject has been trained to make a size discrimination, and on the basis of direction of angle when the subject has been trained to discriminate direction of angle.

2. There are varying degrees of ambiguity of transfer on the basis of size or of direction of the angle.

3. Several explanations of the varying degrees of ambiguity of transfer were considered. The hypotheses of chance variation, direction of movement, the type of discrimination made, the order of the test stimuli, or the direction of the immediately preceding series of movements were found to be inadequate. The general similarity of the figure on the card in the test series to the figures used in the training series was found to be an adequate explanation of the results.

4. The technique of using interpolated test trials with punishment removed can be used on human subjects without their becoming aware of the fact.

5. The nature and variety of the subject's verbal reports as to the basis of his discrimination cannot be determined from an inspection of the stimuli used in training, and the responses made by the subjects.

6. The test stimuli used cannot be divided into two classes, equivalent and non-equivalent; the data must be treated in terms of degree of resemblance. This fact is important in connection with theories of learning.

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